OntoLex-Lemon as a Possible Bridge between WordNets and Full Lexical Descriptions

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Abstract

In this paper we describe our current work on representing a recently created German lexical semantics resource in OntoLex-Lemon and in conformance with Word-Net specifications. Besides presenting the representation effort, we show the utilization of OntoLex-Lemon to bridge from WordNet-like resources to full lexical descriptions and extend the coverage of WordNets to other types of lexical data, such as decomposition results, exemplified for German data, and inflectional phenomena, here outlined for English data.

1 Introduction

We aim at publishing German WordNet conformant data in the Linguistic Linked Open Data (LLOD) cloud.[1] We selected the OntoLex-Lemon model (Cimiano et al., 2016), a successor and World Wide Web Consortium (W3C) standardization of the *lemon* model (McCrae et al., 2012b), in order to represent different kinds of lexical semantics data, since it has established itself as the de-facto community standard for representing lexical data in the Linked Data framework. Guidelines for mapping Global WordNet formats to a *lemon*-based Resource Description Framework (RDF) representation have been published[2] and already some WordNets have been mapped to *lemon*, as described for example in (McCrae et al., 2014).

A candidate for representing German lexical semantics data in OntoLex-Lemon is GermaNet, which is a manually designed WordNet resource for German (Hamp et al., 1997). Developed more than 20 years ago, it represents a very stable, well-tested, and precise lexical semantics resource. However, its access is restricted by its current license. Without such open data access, reuse of GermaNet in global initiatives, such as Open Multilingual WordNet (OMW) (Bond and Paik, 2012), is inhibited. One of the objectives of this paper is to represent lexical semantics data openly linked to other OMW datasets in the LLOD.

Two alternatives compliant with WordNet specifications and available under an open-source license are the *lemonUby* set of resources (Eckle-Kohler et al., 2015) and the Open-de-WordNet (OdeNet) effort.[3] *lemonUby* is an export of lexical data from the large-scale linked UBY (Gurevych et al., 2012)[4], which unites collaboratively and expert-developed resources (e.g. FrameNet and Wiktionary) in English and German, to *lemon*. *lemonUby* contains the German version of Omega-Wiki[5], which encodes WordNet compliant descriptions of German words. OdeNet provides a German resource to the OMW initiative.

A mapping from *lemonUby* to OntoLex-Lemon can be expected to be straightforward due to a high compliance between both models. Thus, this publication concentrates on mapping the WordNet-compliant XML code of OdeNet to OntoLex-Lemon, while in the long run a cross-linking or, where possible, a merging of *lemonUby* and OdeNet in the LLOD is foreseen. We exemplify the richness of lexical descriptions offered by OntoLex-Lemon with the case of components of compounds, German in this submission, and inflectional morphological variations, here in the case of sense variations across English nominal plural inflections.

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[1] See http://linguistic-lod.org/ and (Chiarcos et al., 2012), which describes the first instantiation of the LLOD, while (McCrae et al., 2016) details the further developments of LLOD.

[2] https://globalwordnet.github.io/schemas/#rdf

[3] https://github.com/hdaSprachtechnologie/odenet

[4] http://www.ukp.tu-darmstadt.de/uby/

[5] https://lemon-model.net/lexica/uby/ow_deu/

In the following sections we first describe OdeNet, before presenting the main characteristics of OntoLex-Lemon. In Section 4 we present the current state of the mapping from OdeNet to OntoLex-Lemon, before finally discussing the potential added-value of having WordNets represented in OntoLex-Lemon.

2   OdeNet

OdeNet combines two existing resources: The OpenThesaurus German synonym lexicon[6] and the Open Multilingual WordNet (OMW)[7] (Bond and Foster, 2013). In terms of English resources, it includes the Princeton WordNet of English (PWN) (Fellbaum, 1998). Integrating OpenThesaurus in OdeNet means making use of a large resource for German that is generated and updated by the crowd. A consequence of this approach is that OdeNet needs to be curated, as the authors of the resource mention.

We downloaded the most recent version[8] and first analyzed its content. OdeNet is in an XML format and shares its Document Type Definition (DTD)[9] with other WordNets in the OMW initiative. Lexical entries provide information on different senses of a lexeme, such as "Kernspaltung" or "Kernfission" (*nuclear fission*) in the same synset:

```
<LexicalEntry id="w1">
    <Lemma writtenForm="Kernspaltung" partOfSpeech="n"/>
    <Sense id="w1_1-n" synset="odenet-1-n"/>
</LexicalEntry>
<LexicalEntry id="w2">
    <Lemma writtenForm="Kernfission" partOfSpeech="n"/>
    <Sense id="w2_1-n" synset="odenet-1-n"/>
</LexicalEntry>
```

Lexical senses are grouped to synsets, i.e., groups of word senses with the same meaning. Hierarchical relations are introduced as synset relations, such as here a hypernymy relation:

```
<Synset id="odenet-1-n" ili="i107577"
  partOfSpeech="n" dc:description="a nuclear reaction in
  which a massive nucleus splits into smaller nuclei with
  the simultaneous release of energy">
    <SynsetRelation target='odenet-5437-n'    relType='hypernym'/>
</Synset>
```

Another example is the entry for "Stuhl" (*chair*):

```
<LexicalEntry id="w224" confidenceScore="1.0">
  <Lemma writtenForm="Stuhl" partOfSpeech="n"/>
  <Sense id="w224_49-n" synset="odenet-49-n"/>
  <Sense id="w224_1172-n" synset="odenet-1172-n"/>
</LexicalEntry>

<Synset id="odenet-49-n" ili="i51746"
  partOfSpeech="n" confidenceScore="1.0">
 <Definition>
   Eine Sitzgelegenheit für eine Person, mit einer Lehne
```

```
   im Rücken.
</Definition>
  <SynsetRelation target='odenet-11251-n' relType='hypernym'/>
  <SynsetRelation target='odenet-8518-n' relType='hyponym'/>
  <SynsetRelation target='odenet-20127-n' relType='hyponym'/>
  <SynsetRelation target='odenet-34983-n' relType='hyponym'/>
  <Example>
    Sie sitzt auf dem Stuhl.
  </Example>
</Synset>
```

Access to the lemma information for hypernyms and hyponyms is also possible, for instance for the `odenet-49-n` synset for "Stuhl" it would be:

```
>>> hypernyms("odenet-49-n")
  odenet-11251-n:
  ['Sitz', 'Platz', 'Sitzplatz', 'Sitzgelegenheit']

>>> hyponyms("odenet-49-n")
  odenet-8518-n:
  ['Rolli', 'Krankenfahrstuhl', 'Rollstuhl']),
  odenet-20127-n:
  ['Lehnsessel', 'Fauteuil']),
  odenet-34983-n:
  ['Lehnstuhl', 'Bergère', 'Sessel',
  'Polsterstuhl', 'Polstersessel'])]
```

3   OntoLex-Lemon

The OntoLex-Lemon model was originally developed with the aim to provide a rich linguistic grounding for ontologies, meaning that the natural language expressions used in the description of ontology elements are equipped with an extensive linguistic description (McCrae et al., 2012a; Cimiano et al., 2016). This rich linguistic grounding includes the representation of morphological and syntactic properties of lexical entries as well as the syntax-semantics interface, i.e., the meaning of these lexical entries with respect to an ontology or to specialized vocabularies. The main organizing unit for those linguistic descriptions is the lexical entry, which enables the representation of morphological patterns for each word and/or affix. The connection of a lexical entry to an ontological entity is marked mainly by the `denotes` property or is mediated by the `Lexical Sense` or the `Lexical Concept` properties, as this is represented in Figure 1, which displays the core module of the model.

OntoLex-Lemon, as well as its predecessor *lemon*, have also been deployed for the representation of WordNets, as described for example in (McCrae et al., 2014) and guidelines are available for mapping WordNets to an RDF code compliant to OntoLex-Lemon.[10] A main difference between *lemon* and OntoLex-Lemon is that the latter model includes an explicit way to encode conceptual hierarchies, using the SKOS standard.[11]

As can be seen in Figure 1, lexical entries (lemmas) can be linked, via the `ontolex:evokes` property, to such SKOS concepts, which can represent WordNet synsets. This structure is paralleling the relation between lexical entries and ontological resources, which is implemented either directly by the `ontolex:reference` property or mediated by the instances of the `ontolex:LexicalSense` class.[12] The `ontolex:LexicalConcept` class seems to be best appropriated to model the "sets of cognitive synonyms (synsets)"[13] that (PWN describes, while the `ontolex:LexicalSense` class is meant to represent the bridge between lexical entries and ontological entities (which do not necessarily have semantic relations between them).

More recently the OntoLex-Lemon model has been more and more considered also for modeling lexical data as such, in the context of projects and studies related to the development of digital lexicography, like for example in the past COST action "ENeL" (European Network of e-Lexicography).[14] This development towards a more generic representation model for lexicographic purposes is documented among others in (McCrae et al., 2017).

4 Mapping OdeNet to OntoLex-Lemon

One main issue that occurred due to partly crowd-sourced data in OdeNet was that additional textual information or special characters were added by the crowd to the headwords. A second issue was the improper use of Part-of-Speech (PoS) tags if word classes were different from noun, verb, or adjective or could not be clearly assigned to one of these. These entries are marked with PoS "p", which we filter and link to well-established German lexical data in the LLOD cloud in order to extract the correct PoS information. To clean the data, we wrote a Python script, which not only filters out noisy data, but also maps certain GWN codes (like PoS) to the vocabularies used in OntoLex-Lemon, for example the LexInfo vocabulary for PoS and semantic relations.[15]

As for now, we have an OntoLex-Lemon encoding of OdeNet 120,012 lexical entries, the same number of lexical senses and 36,192 synsets, which are encoded as `ontolex:LexicalConcepts` and included in a SKOS-based conceptual hierarchy, supporting also the description of lexical semantic relations between synsets, like synonymy, hyponomy etc.

The following listings provide details on the OntoLex-Lemon encoding of the first OdeNet entry, which is "Kernspaltung" (*nuclear fission*).

Listing 1: The lexical entry for *Kernspaltung*
```
:entry_w1
  rdf:type ontolex:MultiWordExpression ;
  decomp:constituent :Kern_comp,
              :spaltung_comp ;
  rdf:_1 :Kern_comp ;
  decomp:subterm :entry_w3542 ;
  rdf:_2 :spaltung_comp ;
  decomp:subterm :entry_w23527 ;
  lexinfo:hypernym :synset_odenet−5437−n ;
  wn:partOfSpeech wn:noun ;
  ontolex:canonicalForm :form_w1 ;
  ontolex:sense :sense_w1_1−n ;
  ontolex:evokes :synset_odenet−1−n ;
.
```

In Listing 1 we display the full OntoLex-Lemon entry, which allows us to represent the components of compound words by encoding information as a `ontolex:MultiWordExpression` instance. This class marks any type of entries that can be segmented, thus, including compounds. The term "Kernspaltung" is associated with its two components "Kern" and "Spaltung". Each component represents a full lexical entry with all of its semantic relations. Reuse of components across OntoLex-Lemon entries reveals relations between different instances of `ontolex:MultiWordExpression` based on their component entries. This possibility demonstrates one of the added-values of linking synsets to the (complex) representation of lexical entries, as we can state (see below) semantic relations be-

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ture and content of concept schemes such as thesauri, classification schemes, subject heading lists, taxonomies, folksonomies, and other similar types of controlled vocabulary" (https://www.w3.org/TR/skos-primer/)

[12]Quoting from Section 3.6 "Lexical Concept" https://www.w3.org/2016/05/ontolex/: "We [...] capture the fact that a certain lexical entry can be used to denote a certain ontological predicate. We capture this by saying that the lexical entry denotes the class or ontology element in question. However, sometimes we would like to express the fact that a certain lexical entry evokes a certain mental concept rather than that it refers to a class with a formal interpretation in some model. Thus, in lemon we introduce the class Lexical Concept that represents a mental abstraction, concept or unit of thought that can be lexicalized by a given collection of senses. A lexical concept is thus a subclass of skos:Concept."

[13]Quoted from https://wordnet.princeton.edu/.

[14]https://www.cost.eu/actions/IS1305/#tabs|Name:overview

[15]See https://www.lexinfo.net/ontology/2.0/lexinfo and also (Cimiano et al., 2011).

tween synsets associated to the components of a compound word and its synsets.

Listing 2 below displays the form information associated with entry `:entry_w1` in Listing 1.

Listing 2: The ontolex:Form "Kernspaltung"
```
:form_w1
  rdf:type ontolex:Form ;
  ontolex:writtenRep "Kernspaltung"@de ;
.
```

Listing 3 shows the conversion of the original OdeNet sense information to an instance of the `ontolex:LexicalSense` class.

Listing 3: The lexicalSense associated to the entry for "Kernspaltung"
```
:sense_w1_1-n
  rdf:type ontolex:LexicalSense ;
  ontolex:isLexicalizedSenseOf
    :synset_odenet-1-n ;
  ontolex:isSenseOf :entry_w1 ;
  ontolex:reference
    https://www.wikidata.org/wiki/Q11429 ;
.
```

A sense can be linked to a synset via the property `ontolex:isLexicalizedSenseOf`, which relates a lexical sense to that lexical concept it lexicalizes, here a synset. The entry can be linked to the synset via the property `ontolex:evokes`, as displayed in Listing 1, which is defined as relating a lexical entry to one of the abstract lexical concepts that a speaker of the language would associate with the words in the lexical entry. In contrast to evokes that links to a lexical concept, `ontolex:reference` links to an ontological concept that represents a denotation of the lexical entry, here in the form of a Wikidata entry.

Listing 4 displays the representation of the synset associated with both the lexical entry `entry_w1` and the `sense_w1_1-n`. There we can also see that this lexical concept (synset) is also "evoked" by other entries/senses. For example by the entries for "Kernfission" or "Atomspaltung", which are synonyms of "Kernspaltung". The `lexinfo:hypernym` property provides information on the semantic relation this synset has to another synset.

Listing 4: The `LexicalConcept` (synset) associated with the entry for "Kernspaltung"
```
:synset_odenet-1-n
  rdf:type ontolex:LexicalConcept ;
  skos:inScheme :ODEnet ;
  skos:definition "a nuclear reaction
  in which a massive  nucleus splits
```

```
  into smaller nuclei with the
  simultaneous release of energy" ;
  wn:ili ili:i107577 ;
  ontolex:isEvokedBy :entry_w1 ;
  ontolex:isEvokedBy :entry_w2 ;
  ontolex:isEvokedBy :entry_w3 ;
  ontolex:isEvokedBy :entry_w4 ;
  ontolex:lexicalizedSense :sense_w1_1-n ;
  ontolex:lexicalizedSense :sense_w2_1-n ;
  ontolex:lexicalizedSense :sense_w3_1-n ;
  ontolex:lexicalizedSense :sense_w4_1-n ;
  lexinfo:hypernym :synset_odenet-5437-n ;
.
```

Finally, in Listing 5 we display the entries for the components of the compound word "Kernspaltung". Those components point to the lexical entries they are related to (the entry `:entry_w23527` is for example the one corresponding to the noun "Spaltung" (*split*, *fission*, *separation*, *cleavage*, etc.), which has again its own senses and associated synsets. We can here disambiguate the meaning of "Spaltung" as used in the compound, as being the one of "fission". And the whole compound can then be considered as a hyponym of the synset for "fission".

Listing 5: The two components of entry for "Kernspaltung"
```
:Kern_comp
  rdf:type decomp:Component ;
  decomp:correspondsTo :entry_w3542 ;
.
:spaltung_comp
  rdf:type decomp:Component ;
  decomp:correspondsTo :entry_w23527 ;
.
```

In Listing 1, we can see the information on the sequence those components have in this entry. For sure, those component entries can be re-used separately for other compounds, such as for "Atomspaltung". Thereby, we can collect all the corresponding meanings of a word, also when they are used in compounds and in dependency on their relative position in the compounds. A detailed representation of the decomposition module of OntoLex-Lemon is shown in Figure 2.

In this section we described the current state of the OntoLex-Lemon representation of filtered or cleaned data we can find in OdeNet. Furthermore, we touched upon the possible use of OntoLex-Lemon as a bridge between WordNet-like resources and full lexical descriptions, here exemplified with the case of German compound nouns. In the next section we address the issue on representing sense variants in dependency of the singular or plural inflection of an entry.

5 Added-Values of the Use of Lemon-OntoLex for Representing WordNets

As stated in the preceding section, we see the use of OntoLex-Lemon for representing WordNets as a chance to not only port information from one format to another, but also as an opportunity to extend the coverage of WordNet descriptions to more complex lexical phenomena, beyond lemma and PoS considerations. One case we have been investigating concerns the different synsets that are attributed in PWN to the singular and to the plural forms of one word.

When searching for a word in the PWN interface[16], all potential synsets for this word are returned. While it is possible to actively search for plural forms of a noun, in a vast majority of cases the interface returns results for its un-inflected counterpart because it lemmatizes the queried word. In cases of complementary plural entries, WordNet displays augmented lists of synsets: those associated with the singular, e.g. *people*, and those associated with the plural, e.g. *peoples*. All senses for this example are displayed in Listing 6.

Listing 6: The Synsets for "people" vs. "peoples"
```
people.n.01
  ((plural) any group of human
  beings ... collectively)
citizenry.n.01
  (the body of citizens of a state
  or country)
people.n.03
  (members of a family line)
multitude.n.03
  (the common people generally)
peoples.n.01
  (the human beings of a particular
  nation or community or ethnic group)
```

This differentiation of grammatical number in the representation of synsets and associated meanings intuitively suggests that plural and singular forms do not share all meanings. Regular cases, such as *car* returns no additional synsets and senses for its inflected form *cars*. Thus, it can be assumed that the change of grammatical number does not cause any sense variant in those cases. This means, in turn, that it can be assumed that the availability of additional senses indicates that semantic differences exist between the inflectional forms.

We also observe that querying a plural in Word-Net always results in the listing of all singular senses of a word and, where available, senses specific to the plural. However, this rigorous listing of singular senses also applies to plural nouns that share no sense with their singular counterpart. For instance, querying the pants *khakis* would result in a listing of all senses related to *khaki* and that of the plural. In case a sense exists only for a plural form, it would be desirable for the system to return only the corresponding synset.

Mixed cases exist for this phenomena, the ones where singular and plural share senses and those where senses are specific the singular or plural form. We showcase this behavior with the word pair *letter-letters*. While several senses can be associated with both the singular and the plural form of the lexical entry *letter*, the literary culture sense can be associated only with the plural form. On the other hand, the sense of literal interpretation (e.g. in the case of law texts that are interpreted by the *letter*) is generally assigned to the singular form. In the following listings, we show, in a simplified manner, the way this complex information can be encoded in OntoLex-Lemon.

Listing 7 displays the lexical entry for *letter*. It is stated that two forms are associated with this noun: a singular (the `canonicalForm`) and a plural (the `otherForm`) form. In this simplified entry, we link only to one sense: the one of an exchange between two parties (see Listing 10).

Listing 7: The lexical entry for *letter*
```
:letter
  rdf:type ontolex:Word ;
  lexinfo:partOfSpeech
            lexinfo:noun ;
  ontolex:canonicalForm
            :Form_letter ;
  ontolex:otherForm
            :Form_letters ;
  ontolex:sense
        :LexicalSense_letter_1 ;
.
```

Listings 8 and 9 display the basic encoding for the two possible word forms for the entry *letter*, the singular and the plural forms.

Listing 8: The form for *letter* in singular
```
:Form_letter
  rdf:type ontolex:Form ;
  lexinfo:number
          lexinfo:singular ;
  ontolex:writtenRep
          "letter"@en ;
.
```

Listing 9: The form for *letters* in plural

```
: Form_letters
  rdf : type  ontolex : Form  ;
  lexinfo : number
              lexinfo : plural  ;
  ontolex : writtenRep
              " letters "@en  ;
.
```

The next listing is about the shared sense associated with the lexical entry. As there is a Wikidata entry for the type of entity this sense can refer to, we make use of the `ontolex:reference` property in order to link to this data source.

Listing 10: The lexical sense for the entry *letter* (which can have singular and plural forms)

```
: LexicalSense_letter_1
  rdf : type  ontolex : LexicalSense  ;
  rdfs : comment " letter  as  a  missive  from
      one  party  to  another  ( taken  from
      Wikidata )"  ;
  ontolex : isSenseOf  : letter  ;
  ontolex : reference  < https ://www.
      wikidata . org / wiki / Q133492 >  ;
.
```

Listing 11 introduces the additional lexical entry for the plural form of *letter* that has a specific meaning that cannot be associated with its singular form. Therefore we link this entry only to the plural instance of the class `Form` and to the specific sense encoded in Listing 12, where we additionally formulate the constraint that the usage of this sense is restricted to the plural form *letters*.

Listing 11: The special lexical entry for *letters*

```
: letters
  rdf : type  ontolex : Word  ;
  lexinfo : partOfSpeech
              lexinfo : noun  ;
  rdfs : comment " encoding  singular
              and  plural  entries "  ;
  ontolex : canonicalForm
              : Form_letters  ;
  ontolex : sense
        : LexicalSense_letters_1  ;
.
```

Listing 12: The sense for *letters* in plural

```
: LexicalSense_letters_1
  rdf : type  ontolex : LexicalSense  ;
  rdfs : comment " letters "
        as  " literary  culture "  ;
  ontolex : usage  : Form_letters  ;
.
```

In fact the use of the `ontolex:usage` property could suffice in order to mark that a sense is restricted to a particular inflectional form of an entry, as exemplified below in Listing 13 for the sense of the literal interpretation, without the need to introduce a new lexical entry.

Listing 13: The literal interpretation sense for *letter* in singular

```
: LexicalSense_letter_2
  rdf : type  ontolex : LexicalSense  ;
  rdfs : comment  " letter "
      as  " strictly  literal
          interpretation "  ;
  ontolex : usage  : Form_letter  ;
.
```

OntoLex-Lemon in this case seems to be able to provide for a representation that would support morpho-semantic phenomena. As part of our future work, a possibility to associate senses to forms as well as lexical entries in the OntoLex-Lemon model is investigated.

6 Conclusion

We described our current work consisting in porting a recently developed German WordNet compliant lexical resource, OdeNet, to OntoLex-Lemon, in order to support its publication in the Linguistic Linked Open Data cloud. While processing those data, we noticed that OntoLex-Lemon can be used for bridging the WordNet type of lexical resources to a full description of lexical entries, leading possibly to an extension of the coverage of WordNets beyond the consideration of lemmas and PoS information. We documented this with the example of the representation of components of German compounds and the distinct senses that can exist between certain singular and plural forms of English words.

In terms of future work, other types of full lexical descriptions will be modeled in OntoLex-Lemon and associated with the presented resources. Furthermore, this type of modeling allows for cross-linking to other German WordNets in the LLOD, such as *lemonUby*. This cross-linking effort intends to finally interlink multilingual WordNets in a Linked Data-based format and its rich potential for full lexical descriptions.
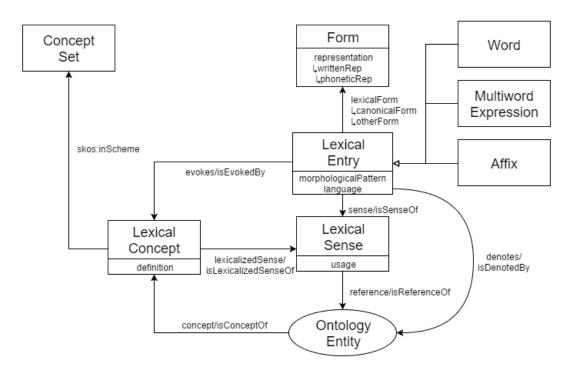
Acknowledgments

Figure 1: The core module of OntoLex-Lemon: Ontology Lexicon Interface. Graphic taken from `https://www.w3.org/2016/05/ontolex/`.
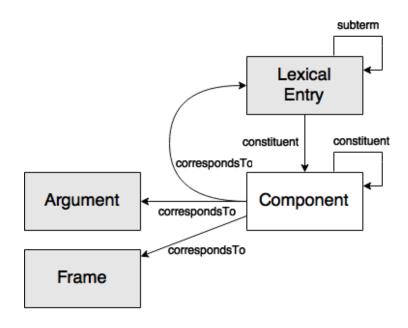

Figure 2: The Decomposition module of OntoLex-Lemon. Graphic taken from `https://www.w3.org/2016/05/ontolex/`.

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